

An attempt of seismic modelling of β Cephei stars in NGC 6910

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Abstract. We present preliminary results of seismic modelling of β Cephei-type stars in NGC 6910 based on simultaneous photometric and spectroscopic observations carried out in 2013 in Białków (photometry) and Apache Point (spectroscopy) observatories.

Keywords. stars: oscillations, open clusters and associations: NGC 6910, stars: early-type, stars: fundamental parameters

1. Introduction

The up-to-date seismic modelling of selected bright β Cephei stars (see, e.g. Aerts et al. 2003, Pamyatnykh et al. 2004, Dupret et al. 2004, Daszyńska-Daszkiewicz & Walczak 2010) already brought some constraints on the convective overshooting from the core and an indication that cores in massive stars rotate faster than their envelopes. The perspectives of the asteroseismology of these stars are therefore promising.

A new way of using asteroseismology is modelling many stars of the same pulsation type simultaneously which is called ensemble asteroseismology. This type of asteroseismology can be done e.g. for members of an open cluster. A prerequisite of a successful asteroseismology is mode identification and determination of some global stellar parameters which can be done much easier for stars in open clusters than for field objects. This is because cluster membership makes that some stellar parameters (distance, reddening, age, chemical composition) can be safely assumed to be the same for all stars, while other parameters (e.g. masses and radii) are strictly related. One of the best candidates for ensemble asteroseismology is the young open cluster NGC 6910 in which Kołaczkowski et al. discovered four β Cephei variables. A new campaign focused on this cluster allowed to detect at least eight β Cephei-type members (Pigulski 2008). The frequency spectra of β Cephei stars in this cluster, arranged according to the decreasing brightness (i.e. mass), show a very interesting progress of frequencies of excited modes. This is exactly what one could expect for p modes in stars located at the same isochrone in a cluster. This qualitative result is a strong argument for trying ensemble asteroseismology for this cluster.

2. Observations and Results

New observations of NGC 6910 were made in 2013. The photometric observations were obtained in Białków Observatory (Poland) during 21 nights. These observations were carried out with a 60-cm reflecting telescope and the attached CCD camera covering $13' \times 12'$ field of view. About 4000 CCD frames through B , V , and I_C filters of the Johnson-Kron-Cousins photometric system were acquired. Spectroscopic observations were carried out with the Apache Point Observatory (APO) ARC 3.5-m telescope and the ARC Echelle Spectrograph (ARCES) during five nights. In total, we have taken 36 spectra of NGC 6910-18 and single-epoch spectra of two other β Cep-type stars: NGC 6910-14 and

Table 1. Atmospheric parameters of analysed β Cep stars in NGC 6910.

Star	$\log T_{\text{eff}}^1$	$\log T_{\text{eff}}^2$	$\log L/L_{\odot}$	$v \sin i$ [km s $^{-1}$]
NGC 6910-14	4.447	4.443	4.182	125
NGC 6910-16	4.447	—	—	149
NGC 6910-18	4.398	4.400	4.025	94

Notes:

¹Based on our spectroscopy.

²Based on Strömgren photometry.

NGC 6910-16. The spectra have a resolving power of 31500 and cover a range between 3200 and 10000 Å. Photometric observations were calibrated in a standard way. For each frame, we calculated aperture and profile magnitudes of the stars using the DAOPHOT II package (Stetson 1987), and then derived differential magnitudes. Spectroscopic observations were reduced with standard IRAF routines.

We determined T_{eff} and $v \sin i$ of the observed stars (NGC 6910-14, -16, -18) using our spectra and the BSTAR2006 grid of non-LTE model atmospheres of Lanz & Hubeny (2007) and the ROTIN3 program. We used also the UVBYBETA code and literature u , v , b , y , and β magnitudes to obtain $\log L/L_{\odot}$ and $\log T_{\text{eff}}$ of NGC 6910-14 and NGC 6910-18. The results are shown in Table 1. In the case of NGC 6910-18 we found that the amplitudes of the two dominating modes with frequencies $f_1 = 6.1549 \text{ d}^{-1}$ and $f_2 = 6.3890 \text{ d}^{-1}$ remained almost unchanged in comparison to 2005–2007 observations. We performed mode identification for this star with the methods developed by Daszyńska-Daszkiewicz et al. (2005) for five stellar models using B , V , and I_C time-series photometry. The evolutionary tracks were computed with the Warsaw-New Jersey evolutionary code adopting the OP opacities, the solar mixture, rotational velocity $V_{\text{rot}} = 100 \text{ km s}^{-1}$, hydrogen abundance $X = 0.7$, metallicity parameter $Z = 0.015$ and no overshooting from the convective core. We identified f_1 as an $l = 3$ mode whereas f_2 can be identified as $l = 0, 1$ or 2 .

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